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Infrastructure development strategy for sustainable wastewater system by using SEM Method (Case study Setiabudi and Tebet Districts, South Jakarta)

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Abstract

The root of pollution problem that occurs in water surface and groundwater is the unavailability of adequate wastewater infrastructure in order to anticipate the rapid development of city with large populations [2]. Jakarta as a capital city with population of 9.733.880 million from the total area of 650 km^2, only has 3% of its total population served by piping system, which are in Setiabudi and Tebet district. The Masterplan of wastewater and drainage (1991-2010) has been made with assistance from JICA through central government, and now it is under evaluation and compilation of new Masterplan 2012-2050 with JICA's assistance. There was no significant progress in wastewater infrastructure development from 1991 to 2001. To know why the wastewater infrastructure is undeveloped and its obstacle issues, it needs a reaserch conducted to society, management, and the government as decision maker. This research is done by using the SEM Method to 270 respondents. The result of this research shows the pathway coeficient which has positive and significant influence to the sustainability which are intitution (0.203), environmental (0.197), technology selection (0.156), financial/economy (0.146) and social-culture (0.128). Those coeficients are used to compile the development strategy for wastewater infrastructure.

Keywords: SEM, strategy of policy, sustainability, wastewater infrastructure

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1. Introduction

The availability of wastewater or sanitation infrastructure is one of the basic human needs with the main purpose of separating human waste from the living environment to prevent diseases [1]. *World Health Organization* (WHO) found that bad sanitation condition causes 85-90% diarrhea in developng country [4] and causes 1,6 million children death under the age of 5 [5]. In developing country, the simplicity and low cost of construction of lavatory (simple hole) without operation and maintenance, contributes in spreading the disease through the ground water contamination [23].

Jakarta as the capital city of Indonesia has similar sanitation issues with another cities in developing countries. In this case, the issue is wastewater problems. Rapid city growth, population growth and migration from vilage to urban without proper planning for wastewater infrastructure, is the root of pollution issues which occur on surface water and ground water [2].

Jakarta currently has been served by sewerage system with grants from central government through *Loan International Bank for Reconstruction and Development* (IBRD). Those infrastructure and its facilities have been built in 1992-1996. To manage those wastewater network, Regional Company for Wastewater Management in DKI Jakarta (PD PAL Jaya) was established, with ± 3% service coverage including Setiabudi and Tebet District. In 1991, *Master Plan* of Wastewater and Drainage (1991-2010) for Jakarta city has been done with JICA Assistance, and become the guideline for next development program, but until 2011 there has been no significant development progress.

Based on study, 77% groundwater in DKI Jakarta has been contaminated by E. Coli [14]. Well water can not be used as a source of drinking water [15] and 82% of rivers has been heavily contaminated[14].

Hence, Jakarta needs a strategy on domestic wastewater development to reach *The Millennium Development Goals* (MDGs) in 2015 where 50% of population has access for basic sanitation and implementing the vision of Jakarta to become a prosperous, comfortable, and sustainable city of service. The study on provision of infrastructure and facility strategy is done to know how the development of sustainable city wastewater infrastructure that can balance the city and population growth, and individual wastewater development not polluted the environmental.

The study has been done in household which has been served by sewerage system (offsite) in Tebet and Setiabudi district. In this study examined the indicators and variables which influenced the sustainability of provision of the wastewater infrastructure and facility in theory, then compiled into teoritical model which will be proven by field data and become data-basis model [3]. Those variables will be analized by Structural Equation Modeling (SEM) [24].

2. Methodology

2.1 Location and Samples

Sampling has been done in Tebet and Setiabudi district, South Jakarta, which has been covered by offsite system (sewerage) through domestic connection. The sub-district for location of study are: Manggarai, Manggarai Selatan, Bukit Duri, Karet, Setiabudi, Karet Kuningan, Menteng Atas, Pasar Manggarai and Guntur.

2.2 Identification of factors that influenced the sustainability

Based on literature study, the factors that influenced the sustainability are as follows:

- Technology Selection (TS); is a latent exogenous variable measured from 4 indicators: system endurance (X1.1), availability of spare part (X1.2), easiness of operational (X1.3), and adaptability

(X1.4).

- Financial (F); is a latent exogenous variable measured from 3 indicators: investment cost (X2.1), O&M cost (X2.2), and local development (X2.3).
- Environmental (E); is a latent exogenous variable measured from 3 indicators: not polluting water sources (X3.1), efficiency of raw material (X3.2), and minimization of wastewater (X3.3).
- Institutional (I); is a latent exogenous variable measured from 2 indicators: regulation and sanction for wastewater (X4.1), and regulation & sanction for environmental protection (X4.2).
- Social-Culture (SC); is a latent exogenous variable measured from 4 indicators: willingness to pay (X5.1), local capacity (X5.2), society acceptance (X1.3), and suitability of local culture (X5.4).

Literatures of factors in sustainable wastewater system showed in this table:

Table 1. Factors on wastewater system

Indicator	Reference
Technology Selection	Nadia Paramita (2009); Nhapi et al. (2004); IHP (2006); Balkema et al. (2002); UNESCO-IHP and GTZ (2006); Flores et al. (2008); Gaulke et al (2009); Peter-Varbanets et. al. (2009); Werner (2009)
Financial	Mucherjee & van Wijk (2003); Warner (2009); Carvalho (2008); Nadia Paramita (2009); Amparo Flores et al (2008)
Environmental	Mucherjee & van Wijk (2003); Carvalho (2008); Warner (2009); Belkema, Weijers & Lambert (1998); Bradley, Daigger et al. (2002)
Institution	Pushpangadan dan Murugan (2008); Balkema et al (2002); Bradley, Daigger et al. (2002); Werner (2009)
Social Culture	UNESCO-IHP and GTZ (2006); Werner (2009); Belkema, Weijers & Lambert (1998); Carter et al (1999); Amparo Flores et al (2008); Werner (2009)

2.3 Survey Method and Variable Measured

Data was obtained from primary and secondary data. Primary data is obtained directly from respondent by interview using questionaire, observation or both combined. While secondary data is obtained from related institution. The data is grouped into variables of observation/indicators which consists of technology selection, financial, environmental, institution, and social-culture.

2.4 SEM Modelling Technique

Observation variables on sustainability is compiled based on literatures which then formulated by diagram line of theoritical model, to develop the model into data-basis. The validity and realibility of 270 questionares are tested by confirmatory factor analysis approach. First order is the validity and realibity test from the composite variables to its indicators to know wheather the questions in the questionaire is quite representative (valid) and quite accurate or consistent (reliable).

The validity test of composite variables could be done by using the refusal criteria H_0 with possible hipothesis are:

- $H_0 : \lambda = 0 \approx$ variable is not valid as indicator of latent variable.
- $H_1 : \lambda \neq 0 \approx$ variable is valid as indicator of latent variable.

Where the corelation value > 0.5 and sig (2-tailed) < $\alpha = 0.05$.

Reliability test is using the interval consistention method through valid conbrach alpha > 60%.

The second order is done by validity and realibity test to measure the level of influence significancy between one latent variable and its indicator.

- The validity test is done by using the Confirmatory Factor Analisys (CFA) by using AMOS 18 programme where loading factor > 0.5 and value of p on regression weight < 0.05.
- The realibity test is done to know how far the the measuring instrument can be trust. Reliability is consistency of a measurement. High realibity showed that the indicator has high consistency in measured its laten variable. To measure the realibility *costruct reliability* (CR) can be used as follows (Hair and all, 2006:777).

$$CR = [\sum^n \lambda_i]^2 / ([\sum^n \lambda_i]^2 + [\sum^n \delta_i]) \qquad (1)$$

Where λ_i is a loading factor for each latent variable and δ_i is an error variance for each construct/latent. The minimum limit value used to assest if CR has good reliability is ≥ 0.70 and p variance error < 0.05. The result of validity and realibility test is shown on te table 4 (appendix A). To express the relationship of causality between the various construct, an equations of Structural Equation Model (SEM) is built as follow:

$$\eta = \gamma_1 \xi_1 + \gamma_2 \xi_2 + \gamma_3 \xi_3 + \gamma_4 \xi_4 + \gamma_5 \xi_5 + \zeta \qquad (2)$$

Where :

η = Sustainability system (laten variable intervening/endogen)
ζ = Recidu factor
λ_i = Loading Factor Observe Variable
δ_i = Error variance on exogenous Observe Variable
ε_i = Error variance on endogenous Observe Variable
X = Exogenneous Indicator
Y =Endogeneous Indicator

To build a good model, it has to be tested with suitability tests indicated by fit and proper criterias, as shown in the table 2 below.

Table 2. Criteria Goodness of Fit

Goodness of Fit	Cut-Off Value
χ^2 *Chi-Square Statistic*	Expected small
χ^2 *Significance Probability*	≥ 0.05
GFI	≥ 0.90
AGFI	≥ 0.90
CFI	≥ 0.08
RMSEA	≤ 0.08

Source: Hair, et al, 2010

3. Results and Discussion

3.1 Study result

The test result with fit and proper criteria to assess the viability of a model could be seen on the following table 3; the table also shows good result on 6 criteria, which means there is a match between the theoretical model with the data, therefore it can be said that the model could be accepted with no modifications are required on the model.

Table 3 Test Result with *Goodness of fit*

Criteria	Cut – Off Value	Calculation Result	Remarks
Chi-Square	Expected result	210.437	χ^2 with df=137 is 165.316 Good Enough
Significance Probability	≥ 0,05	0,000	Not Good
RMSEA	≤ 0,08	0.045	Good
GFI	≥ 0,90	0,927	Good
AGFI	≥ 0,90	0,899	Good
CMIN/DF	≤ 2,00	1.536	Good
TLI	≥ 0,95	0.987	Good
CFI	≥ 0,95	0.990	Good

Source : Appendix 12 (Model fit Summary) prepared

3.2 Empirical Model of the Relation of Exogenous variables on the Endogenous variables

Empirical model of the relation of exogenous variables on the endogenous variables after conducting validity and reliability test and test using fit and proper criteria could be depicted as follows:

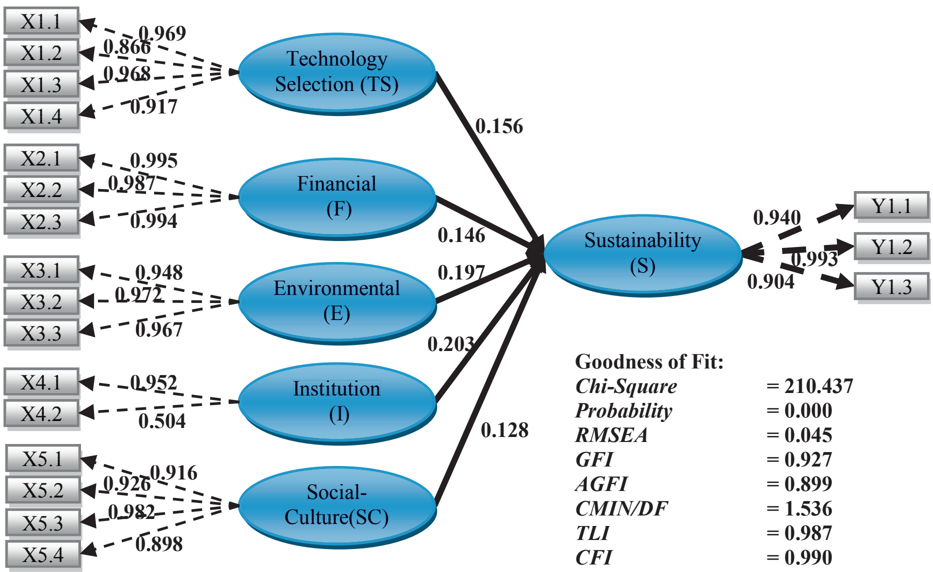

Figure 1. Empirical Model of the Relation of Exogenous on the Endogenous

From the empirical model of sustainability, line coefficient is obtained as hypothesis in the research, which is presented in structural equation as follows:

$$S = 0.156\ TS + 0.146\ F + 0.197\ E + 0.203\ I + 0.128\ SC \qquad (3)$$

Table 4. Test Result for Line Coefficient on the Sustainability Model

Variable	Line Coefficient	C.R	Probability	Remarks
Technology Selection (TS) → Sustainability (S)	0.156	2.505	0.012	Significant
Financial/Economy (F) → Sustainability (S)	0.146	2.485	0.013	Significant
Environment (E) → Sustainability (S)	0.197	2.484	0.013	Significant
Institution (I) → Sustainability (S)	0.203	2.460	0.014	Significant
Socio-Cultural (SC)→ Sustainability (S)	0.128	1.974	0.048	Significant

Based on the table 4 above, the interpretation for each line coefficient are defined as follows :

All of the exogenous variables have positive and significant effect on the Sustainability (S). It can be seen on the line coefficients which are marked as positive from 0.128 to 0.203 with C.R. value from 1.974 to 2.505, and the significance of probability (p) are obtained at 0.012 to 0.048, which are smaller than the determined significance level (α) of 0.05.

Thus, all exogenous variables affect directly on Sustainability (with the value at 0.156 on the selection of technology, which means that whenever there is an increase on Technology Selection (TS), it will raise the Sustainability (S) of 0.156). It is also similar to the other latent variables.

4. Conclusion

Based on the results of research and discussion, it could be concluded that the institutions, environment, technology selection, financial/economy and socio-cultural conjointly affect the sustainability. Variables that provide the dominant influence on sustainability in respectively are institution (0.203), environment (0.197), technology selection (0.156), financial/economy (0.146) and socio-cultural (0.128), all which have a positive and significant impact on sustainability. The coefficients of the variables that affects sustainability are used to prepare the strategies for the provision of wastewater infrastructure, which are the implementation of legislation and legal sanctions, saving and recycling wastewater, the selection of appropriate technology for limited space and the necessity for investment and society involvement. From the variable observed in sustainability, 83,3%. the society members sampled agree that sewerage system makes the environment and health better.

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Appendix A

Table 5 Test of Validity and Reliability of Research Variables

Variable	Indicator	*Loading Factor*	p-value	Infromation	*Composite Reliability*	Information
Technology Selection (TS)	endurance system (X1.1)	0.969	0,00	Valid	0,963	Reliabel
	easiness of spare part (X1.2)	0.866	0,00	Valid		
	easiness of operational (X1.3)	0.967	0,00	Valid		
	adaptability (X1.4)	0.917	0,00	Valid		
Financial (F)	investment cost (X2.1)	0.995	0,00	Valid	0,995	Reliabel
	O&M cost (X2.2)	0.987	0,00	Valid		
	local development (X2.3)	0.994	0,00	Valid		
Environmental (E)	not polluted the water source (X3.1)	0.948	0,00	Valid	0,974	Reliabel
	efficiency of row material (X3.2)	0.971	0,00	Valid		
	minimalize the wastewater (X3.3)	0.968	0,00	Valid		
Institutional (I)	regulation and sanction for wastewater (X4.1)	0.952	0,00	Valid	0,716	Reliabel
	regulation & sanction for environmental protection (X4.2)	0.504	0,00	Valid		
Social-Culture (SC)	willingness to pay (X5.1)	0.916	0,00	Valid	0,963	Reliabel
	local capacity (X5.2)	0.925	0,00	Valid		
	society acceptance (X5.3)	0.983	0,00	Valid		
	suitability of local culture (X5.4)	0.897	0,00	Valid		
Sustainability (S)	financial gain (Y1.1)	0.939	0,00	Valid	0,962	Reliabel
	diarrhea mortality (Y1.2)	0.993	0,00	Valid		
	environment quality (Y1.3)	0.903	0,00	Valid		

Information:
1. Loading factor > 0,5
2. p-value (regression weight) < 0,05
3. Composite Reability (CR) > 0,7